

On A Patent Analysis Method for Technological Convergence

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Abstract

An important feature in recent innovation trend is the merging and overlapping of technologies, i.e. the technological convergence. The paper proposes two approaches using patent data to examine the technological convergence. First, we conduct a patent network analysis using the patent citation, which can be considered as a knowledge flow among technological fields. Second, in order for more specific analysis, the co-classification among technologies is carried out to measure the convergence intensity, rate, and coverage. Finally, by using the coverage intensity and rate, we propose two portfolio matrices to manage the technological convergence.

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Keywords: Technological convergence, patent, citation, co-classification, portfolio

1. Introduction

An important feature in recent innovation trend is the merging and overlapping of technologies, i.e. the technological convergence. Emerging sectors are characterized by rapid development of technologies based on a gradually broadening range of scientific and technological fields and increasing the necessity of cross-scientific research. At the same time, to meet the more complicated customer demands, the merging of different technologies has become indispensable. The convergence of technologies and underlying knowledge bases has accordingly induced a variety of industrial points of inflection. Various sectors of the industry have started to provide products and services with similar functions, which result in blurring market boundaries. Since 1990s, for example, sectors of the information and communication technology have tended to converge [1] and more recently this phenomenon can also be found in various other industries like the chemical, the food, or the pharmaceutical industry. In industries such as information technologies, consumer electronics and telecommunications, formerly distinct sector boundaries have already largely faded [2].

The resulting new industry segments present firms with both opportunities and threat. On one hand, a plethora of opportunities for new fields of business and economic growth emerges. On the other hand, the

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firms have to employ knowledge and technologies not within their traditional framework of expertise and will be facing many new competitors, who may have been strong incumbents in either own segments prior to the formation of the new segment [3]. It will be helpful for the firms to understand the emerging trends of technology convergence in establishing a strategy for the opportunities and threats [25].

With all the importance of the convergence between several technologies, however, the previous studies on convergence have taken particular attention on a special technology like IT, BT, NT, etc or they tried to analyze the convergence in one technology, for example, on IT [1][4] or on BT [5][6] separately. Though the recent studies start to be interested in the convergence among several technologies, they focus only on a particular technology [7] or a conceptual framework to explain the relationships between IT and BT using case studies [4]. Because of the lack of data on convergence between two technologies, relatively less research has been done on identifying and analyzing the overall inter-disciplinary relationships between technologies.

Therefore, this study aims to propose a method to measure the convergence between technologies, which will shed light on the evolution of the relevant industries from a macro perspective, and facilitate precise understanding on the structure of the industries and the structure dynamics, deriving recommendations from a retrospective to a predictive context. In particular, we take a quantitative approach using patent data. Specifically, citation analysis is employed to analyze the relationships between technological fields and further co-classification analysis is followed to identify converging technologies at the micro level in the emerging converging technological fields. In many cases, the previous approaches to measuring the convergence have focus mainly on symptom-dealing with the new situation within the firm and within the industries, rather than on examining the nature of the underlying mechanism for a proactive approach to dealing with convergence [4]. The patent-based approach is expected to help understand the convergence process as a form of technology innovation, considering that patents are a proxy of innovation, and to further relate the dynamics of convergence to respective dynamics of innovation process.

2. Technological Convergence

2.1. Convergence concept

The term ‘convergence’ is often used but rarely defined buzzword [8]. In general, convergence is used for the description of at least two discernable items moving towards union or uniformity or a blurring of boundaries between at least two hitherto disjoint areas of science, technology, markets, or industries [9]. The most frequently mentioned concepts include industrial and technological convergence. In the early works, the two types of convergence were regarded as the same thing in that industry convergence is the consequence of technology relatedness. However, while in many cases they are strongly related, they are still not interchangeable [10]. To clarify these concepts, the previous research tried to classify a variety of convergence definitions. Particularly, making use of the paradigm of evolutionary theory, Hacklin [11] divides the process of convergence into four stages, which are knowledge, technology, application and industry convergence. In the similar way, Curren and Leker [7] discern between four loci of convergence – science, technology, market, and industry.

After two decades of movement towards convergence, there exists a broad literature based studying the phenomena from different perspectives, which can be classified largely into three categories. The first category focuses on ex ante definition of convergence on a theory level to analyze and explain the current phenomena. For example, different stages of convergence are defined from the perspective of evolutionary economics [4][11], or the phenomena is analyzed using the theory of industrial organization or value network [12][13]. The second category aims to develop strategic or policy implications incurred by convergence [2][14]. The final category pays attention to a particular converging technology such as

broadcasting and telecommunications convergence technology [15] and convergence components and materials technology [16].

In spite of the meaningful contributions, the previous studies are subjected to the following limitations. First, most of them use concept frameworks and case study to analyze the mechanism of the convergence [1]. A quantitative approach or empirical analysis of the convergence will add great value to the existing literature. Second, the previous studies generally investigate convergence from a micro-perspective, using company-level sample data or a limited set of technologies. However, micro-analysis cannot reveal the whole picture of convergence and macro-level analysis can be complementary to the existing literature. Finally, the existing studies have focused on the convergence at the industry or application level but little research was done at the knowledge or technology level. Additional exploratory and explanatory research will be helpful to analyze the mechanism of technological convergence that lead to industry convergence. The main contribution of this research is that it proposes a novel method to measure technology convergence. The method is different from pervious literature in that it measures technology convergence and knowledge relatedness from a macro-level using well-established patents data. In addition the method can measure not only static technology convergence but also the dynamics of technology convergence using a patent index to capture the dynamics.

2.2. Convergence measurement

Measuring convergence is related to two streams of literature where one measures corporate diversification [1][17] and the other measures knowledge/technology relatedness [18]-[20]. The formal generally uses case studies or input-output analysis focusing on industry convergence, while the latter stream adopts measures based on patent data to analyze technology convergence.

Patent documents are an ample source for technical and commercial knowledge about technology progress and innovative activity [21] and have been a regular source of information to gain insight into technology dynamics. In particular, patents have been employed in the context of the technology-driven convergence of electronics, computers, and telecommunications [7]. One of the advantages of the use of a patent is that it helps identify general technology trends based on its relation to other patents and publications. Another advantage is that it is easily analyzed as a temporal sequence using the data of application and publication. Of varied patent information, we use patent citation and patent co-classification analyses in this research.

First, a patent citation is defined as the frequency that a patent is cited in subsequent patents, which reflects the impact of its technological innovation and the pervasiveness of its technological information [22]. If citation indices such as citing-cited intensity and linkage are measured between technologies, patterns of technological innovation and knowledge flows can be identified [23]. Consequently, citation analysis has long been applied to understand linkages between industries or technologies, and further knowledge flows among them are investigated to identify the trends of knowledge or technology convergence.

Second, a patent classification refers to a way the examiners of a patent office arranges patent documents according to the technical features of inventions. Since the same document may be classified in several classes, the co-classification information can be used to identify the relationships between technologies. If more and more patents are classified both by two classes, technologies in the two classes may have more in common and are getting closer to each other. By adopting the degree of co-occurrence of classes, it is possible to quantitatively analyze the interdisciplinarity of technologies. The relevant method was suggested in 1960s [23] and was later applied in a science and technology context [24]. We assume that technologies with the high degree of co-classification are converging technologies.

3. The Patent-based Method for Convergence

3.1. The procedure of the patent-based method

The overall procedure consists of four steps (see Fig. 1). In the first step, the patents of two target technologies are collected and grouped by technologies and technological fields, where technological fields are defined to be collections of technologies. The next two steps investigate the phenomena of convergence of those target technologies based on these data.

The second step examines the *convergence of technological fields* by identifying the overall relationships between two target technologies with respect to knowledge flows at the macro level. We assume that greater knowledge flows between technological fields indicate a greater likelihood of convergence between the fields. Since knowledge convergence is the first stage of convergence, the analysis of knowledge flows is an appropriate method for identifying possible current and future convergence between technological fields. We propose a patent citation analysis, which is one of the most popular techniques for analyzing knowledge flows between technological fields.

The third step focuses on a set of closely related technological fields. For these emerging converging fields, detailed analysis at the micro level is conducted to examine the *convergence of technologies* that have driven the convergence of the fields. We use co-classification analysis to measure the convergence. If a patent is classified into classes of both two target technologies, the relevant technology can be used in both areas. This measures the convergence of the technologies more directly. To quantitatively measure the degree of convergence, we design two patent indexes—intensity and coverage—based on the co-classification measures. The intensity index measures the strength of convergence between two technologies, and thus is calculated for pairs of technologies. If two technologies—one in A technology (ex, IT, BT, NT, ST, CT and ET, etc) and the other in B technology—share many co-classified patents, their convergence intensity will be high. The coverage index measures the coverage of convergence for a technology, and so is calculated for each technology. If a particular technology in A technology is co-classified by many other technologies in A (or other Technology), it will have a high coverage index.

In the final step, we develop two portfolio maps based on the index values to forecast the future of two target technologies convergence in the emerging converging fields and ultimately to help identify future technology opportunities from the convergence. The portfolio maps are described in the next section.

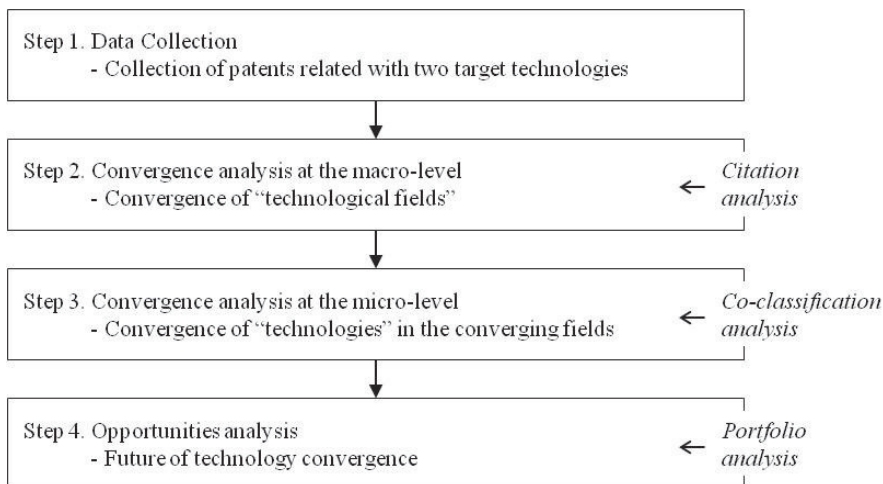


Fig. 1. The procedure of the patent-based method for Technological Convergence

3.2. Convergence portfolio map

The *convergence intensity map* (see Fig. 2) uses intensity index values to create a portfolio map for target technology pairs. The technology pairs are mapped onto the two-dimensional space according to the degree of convergence intensity and its rate of increase. Based on this, the technology pairs are classified into the four groups shown in Fig. 2.

Technology pairs in the first quadrant are *strongly convergent* because many of the relevant patents are co-classified, leading to high intensity values, and the tendency to co-classification is rapidly increasing, giving a high rate of increase for the intensity. The directions of technology convergence are determined to some extent, and great opportunities are expected from the technology pairs in this quadrant. Technology pairs in the second quadrant are *emerging* convergence sets since their co-classification intensities are relatively low but increasing rapidly, indicating that they will soon move to the first or fourth quadrant. Since the dominant directions of technology convergence have not been established, various opportunities for technology convergence can be investigated. Technology pairs in the third quadrant have low values for both the intensity and its rate of increase. Therefore, the technologies in these pairs are *relatively separated* in their evolutionary process. Technology pairs in the fourth quadrant are *converged* because many patents are co-classified, leading to high intensity values, but their rates of increase are small. No further significant convergence is expected from these pairs, but for limited technology sets, strong convergence is observed and is becoming general.

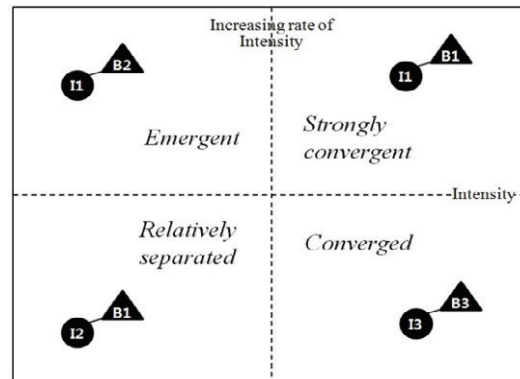


Fig. 2. Convergence intensity map.

The *convergence coverage map* (see Fig. 3) uses coverage index values to create a portfolio map for target technology pairs. In contrast to the intensity map which maps a technology pair, the coverage map maps individual technologies. For each technology, we find the coverage index value and its rate of increase. We then map the technologies onto the portfolio map and classify them into four groups.

Technologies in the first quadrant are *expanding* their areas of convergence. These technologies have converged with many other technologies and are still expanding their areas of convergence, thus playing a major role in the convergence of two target technologies. Technologies in the second quadrant are in their *infancy* of convergence but have the potential to facilitate the convergence of two target technologies. They currently affect only a small set of other technologies but are expected to expand their areas of convergence, thus opening up new possibilities. Technologies in the third quadrant have relatively low coverage values and rates of increase. These technologies have evolved *relatively independently* of other technologies. Technologies in the fourth quadrant are *extensively converged* with other technologies but do not have many new areas of convergence. The technologies in these areas may be increasing their

convergence intensity, and thus new opportunities can be observed from the increasing depth of convergence.

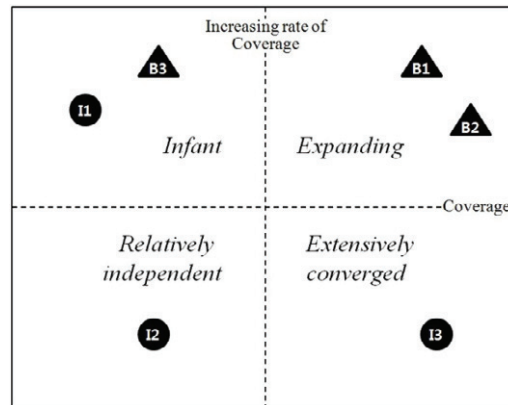


Fig. 3. Convergence coverage map.

4. Conclusion & Further Study

We propose a new patent-based method using patent citations and co-classification to investigate the technological convergence between any two technologies. We first carried out a field-level analysis, identifying the promising technology fields that promote significant convergence by active links of knowledge. We then performed a technology analysis, measuring the intensity and coverage of convergence. Finally, we conducted an opportunity analysis to analyze the current state of convergence by constructing two portfolio maps: a convergence intensity map and a convergence coverage map.

Although this study extends the application of patent network analysis and patent co-classification analysis to the identification of technological convergence, there are some limitations. First, although patent information has been widely accepted as a proxy for technological innovation and has been used for technological convergence, there is no guarantee that technological convergence can be fully explained by a patent database. Second, we have developed the convergence between two technologies or fields. However, more than two technologies could be involved in convergence. Finally, above all, as a subsequent action, the empirical analysis using the proposed method must be necessary for various technologies such as IT vs. BT or IT vs. NT, etc. Such an empirical study can make us verify the usefulness of the proposed method and find potential pitfalls.

Acknowledgements

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology(2011-0007373)

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